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# Natural Materials – Nature of Materials

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The material world is recently and very rapidly changing; altering the relationships between materials – the substance of everyday life – and designers – the professionals who are responsible for transforming materials into daily life objects. This vibrant context prompts us to explore and attempt to conceptualise these fluid relationships and review conceptual tools that will help to open up the scope of materials based research in design. To address the multiple and multi-faceted relationships designers are situated in, we borrow concepts from social sciences that explore materiality within its multiple environments. We draw on conceptualisations of materials as active and as having capacities to bring about change and proliferate relations, and responding to new developments of biotic materials. By considering historic materials, particularly milk-based plastics, we propose a new category of autonomous materials. We discuss the emerging designer-material relationships with the hope of directing future enquiry into materials and discuss the implications of a new class of materials – the 'autonomoids' – for design research.

*materials, milk plastics, biotic materials, materials based research*

## 1 The Emerging Material World and Conceptual Dilemmas

This paper aims to elaborate on the emerging and changing designer-material relationships within the current developments in materials science and product design fields. The material world is "vibrant" and "active" (Bennett, 2010), literally in the sense that atomic particles are always on the move, but also in the sense that the material circumstances of our daily lives, its materiality, is constantly changing. But materials are also "active" in the sense of the word found in science and technology studies (STS), because they *cause* change, and *affect* other human and non-human actors, as well as affecting professional and daily life practices.

In recent years, we are talking about a materiality where materials are "smart", where materials "grow" themselves, where they are natural, or synthetic, or biotic… These materials *act*; a glove using a soft, flexible non-Newtonian material, becomes hard and strong when hit by a hammer. These materials are *alive*; fungus put in a chair-shaped mould, grows to become a chair. It is as if

these materials can *take on human responsibilities* regarding our duties to protect nature. Even plastics, which have a reputation as the most 'anti-nature' materials, can be nature-friendly or nature-derived, depending on what is inscribed in their molecular structure. New production machinery can *develop* new materialities, with rapid prototyping methods generating shapes quickly and apparently without effort. And material things can *communicate* with each other, through the "internet of things".

For designers, the professionals, who are assigned the task of adopting materials in forms that both suit the daily life needs of humans and protect nature, and who thereby alter and modify both humans and 'nature', these developments are crucial as well as confusing. Because there are various disciplines interested and involved in design and production processes, design's pragmatic relationship to materials is varied and operates with quite inconsistent conceptualisations of them - materials are both substances that are shaped in the hands of designers to find their place in our everyday lives, and they are also described as if they have independent human-like characters – the 'warmth' of wood, the 'spookiness' of fungi. Dominating this pragmatic relationship to materials are culturally defined conceptions of nature, which are in themselves complex, increasingly characterised through what seems to be a limiting nature-culture or nature-design distinction, expressed as a material-designer/human-nature divide.[1] The relationship of humans, in general, to nature is complex and contradictory – we act "against" nature when we use the earth's finite resources, but if we think about human organs or tissues, we know they are natural, biologic, even as we try to use bio-medical science, and new materials, to imitate, repair or replace them.

Thinking through these material developments in terms of this range of perspectives, generates a number of questions, all variously related to design. Some are to do with their implications for designers' professional identity, such as whether materials science and product design need to form a new collaboration, and if so, how much of an engineer is the designer and how much a materials scientist. Some are more fundamental, such as asking where materials end and where the product starts, even to the extent of asking what it is valid to call *a material*, how to address active-liveness of materials for pragmatic purposes of design and designing. This raises the question of at what point does the *design* start between the level of material development and of use? The perplexing extent of material formulations, and the degree to which materials can be modified means these are boundaries that are shifting and blurred and moved us to explore the "nature of materials" within these new material developments.

To explore these multi-faceted relationships, and ontologies of materials we bring in approaches from social sciences, mainly material culture and science and technology studies, and attempt at a working conceptualisation of materials. This perspective provides us with a new way of addressing these emergent and fluid relationships. We nuance their active-ness by introducing the concept of "autonomy," and discuss the implications of bringing in a sociological approach, i.e., pointing to the relations making up material reality – and arriving at this new conceptualisation of "autonomoids." Some of the current developments in materials, such as changing qualities of plastics from "synthetic" and "harmful" to "bio-" (as in bioplastics) or self-growing materials as in the case of biotic materials, provide good examples of changing relationships between materials and humans, and especially from a designerly perspective for materials based researches in design, in terms of the relationships between materials and makers/designers. We focus on milk plastics, such as Casein, that are "derivatives" of milk. These materials allow us to elaborate on nature/design relationships with reference to a wide range of industries over time, because milk-derived plastics have been used in various sectors and have a history almost as long as that of synthetic plastics. They also raise rich

[1] The recent Design History Society conference DHS 2017: Making and Unmaking the Environment engaged with this nature-design divide saying designers are "either blamed for causing environmental problems, or hailed as possessing some of the competences that could help solving those problems." (conference call accessed on 11th Mar 2018 from https://www.designhistorysociety.org/conferences/view/dhs2017-making-and-unmaking-the-environment)

conceptual matters related to a range of concerns about bacteria, hygiene, nature, and sustainability.

In what follows we first introduce the theoretical framing that informs our exploration of the relations folded into milk plastics, then present our analysis of milk plastic's making. This analysis leads us to our conceptualisation of certain materials as "autonomoids," and in the concluding section we elaborate on design-material relationships, and discuss the ways in which "autonomoids" may contribute to design practice.

## 2 Conceptualising Materials

> "Every material is a becoming" (Ingold 2012: 435)

Various approaches to materiality are relevant to the design discipline. Because design's interests and concerns are varied, approaches from different disciplines have been distinctly useful for, and applied to design research. Due to the social as well as technological nature of the practice, methods and approaches from social sciences as well as engineering disciplines are employed in exploring design's relationship to materiality. For example, dominated by concepts derived from engineering approaches to human-machine relationships, ergonomics obtains data through physical and morphological measurement methods (Dreyfuss, 1967). However, this is not comprehensive enough to explain humans' interactions with materiality as we are cultural and emotional, as well as physical, beings. The Design and Emotion umbrella – including design for behaviour change and some approaches to interaction design – uses theories derived from cognitive psychology and semiotics, gathering data through mainly quantitative methods to understand users' interaction with designed objects (Desmet & Hekkert, 2007). Karana (2009, 2017) in her many works makes a timely inference to the field through her work on materials by stating that material selection tools and approaches derived from engineering disciplines are inadequate in addressing multi-faceted relationships through which users appreciate materials (and materiality), and proposes better suited models for design to study these complex relationships.

Against this background, we want to explore more in depth sociologically oriented approaches from material culture, design anthropology and science and technology studies. These explore the phenomenological relationships of social and technical relationships folded into design objects in general and materials at a more fundamental level. Through objects and daily practices, in which objects are utilised, scholars explore the processes that are implicated in designing and the ways objects come to be (Clarke, 2011; Molotch; 2005; Shove, Watson, Hand, & Ingram, 2007).

The ways in which materials seem almost to act like humans, or are ascribed human-like properties in this process, resonates with Jane Bennett's ideas. In her political philosophical account of materials, she concentrates on material's active liveliness: "a creative materiality with incipient tendencies and propensities, which are variably enacted depending on the other forces, affects, or bodies with which they come into close contact" (2010: 56). She does not distinguish between the agency of materials and humans, which she refers to as "life". She maintains that materials are "life", just as much as human beings. Moreover, as Bennett (2010) argues materials are *active* in shaping the environments in which they are *enacted*.

Recent studies of industrial materials from different sociological traditions point to the, in Shove et al.'s (2007) terms, "mutually constitutive" relationships among human and non-human actors. For example, Misa's (1995) STS account of steel shows us how steel transformed transportation and made a whole civilisation mobile, meanwhile getting defined and patented *as* steel through negotiations among various producers and stakeholders. Schaztberg's (2003) business historical account of aluminium reveals complex interrelations between human practices and material

developments, showing that canned foods revolutionised how we buy food and organise food stores. In Klein and Spary's (2009) book that takes a material culture perspective on the materials of early modern Europe, Orland's (2009) chapter elaborates on the making of milk in relation to different disciplinary traditions, their material culture and practices. Bensaude Vincent and Stengers (1996) conceptualise this as "informed materials" to explain that materials are already inscribed with knowledge about the environment into which they are born. Extending their idea, Barry (2005) shows the ways in which pharmaceutical materials are already informed with what is required - existing information technologies, patents and laboratory equipment. Studies on different materials suggest that materials are fundamental but non-fixed. As these scholars emphasise, as much as the different environments of which materials become a part are involved in defining (at least temporarily) their qualities, the materials themselves are also active in making their own qualities.

This brings us to the opening quote of this section, as Ingold (2012: 435) suggests: "every material is a becoming." In his review of recent explorations of the material/ agency nexus, he suggests that materials and humans are "knotted" together and they "co-respond" to each other. His term "correspondence" is a nuanced term explaining the co-constitution of different worlds, human and material, to which he assigns individuality and activeness in mutual co-responses to effects. He honours the entanglement of our "lines of life" with materials in a "meshwork" that is governed by correspondence rather than hylomorphic form-giving (2012, 2007), and notes Karen Barad's call to allow 'matter its due as an active participant in the world's becoming, in its ongoing "intraactivity"' (2003: 803).

However, while we strongly subscribe to the need to engage with materials with this degree of intimacy and ambition, we wish to be less abstract than are Barad and Bennett. And also we want to clarify that this discussion is not limited to only new-age and biotic materials. As Daniel Miller (2007) levels a charge of romanticism against Ingold's approach to materials and materiality, evident in the prevalence of 'traditional' materials, and artisanal rather than design-related examples in his work. Ordinary materials and traditional materials also correspond. However, Miller's (2007) ideas that materials (and objects) are not an end in themselves, but that they are processual actually confirms the Ingold's (2012) ideas materials as a becoming, and as a process; they are constantly in the making, and particularly so in the case of multiple enactments of a material – "Parkesine has multiple coexisting incarnations – as medallion, as comb, as card case or pen" (Shove et al, 2007: 102). However, Miller (2007) is concerned about individual processes. So while we are concerned with 'lines' of material development, as Ingold might have it, it is in a way a literary engagement with those lines – helping to develop 'a conceptual language as well as new forms of material practice' as Jenny Bergstrom puts it (2010: 172). Many of Ingold's principles do of course hold in this approach. As a material is invented and comes to be, comes to mean, it does so because it corresponds in some way(s) with human practices, both everyday life practices and design practices, which at the same time are bringing it about, or more properly in Ingold's terms perhaps, helping it to come forth, sometimes using exploratory hands-on approaches to material development. As such, as well as being attendant to individual stories and histories of different materials, we strive to achieve broader conceptualisations that can be applied to material engagement in general.

Within this perspective design researchers have worked with these fluid meanings and multiple environments. Fisher (2004), who focused on users' relations to materials has shown plastic, the modern marvel material appears "tacky" in certain contexts and "smelly" at times. Tonuk (2016) working on bioplastic materials and products into which they are made, focused on how materials come to be and the resulting material-product relationships. She has shown that qualities of these materials, the meanings and values attached to them, vary depending on the different environments in which bioplastics circulate, and that these qualities are negotiated among different actors. Hence, she has conceptualised materials as "temporally specific phenomena" (Tonuk, 2017).

Even this brief analysis has far reaching consequences for shaping how most effectively to conceptualise materials in design – rather than being stable entities that can simply be "specified",

materials appear as a “processual” phenomenon without fixed meanings or interactions. Moreover, this view emphasises the designer’s agency, their role in *making* material meanings, as well as being affected by them, over a view of designers as passive receivers of the meanings that users associate with them. Technical approaches down play the point that designers sit in an environment of multiple dynamics. While public opinion likes to think of them as the creative brains, out of which somehow ideas flourish, the design process is bounded by its environment, production technicalities, the availability of materials etc. Designers are but one of the agents with which things interact in their becoming.

This theoretical framing broadens the scope of the environment for design studies of materials, and it acknowledges that this context includes multiple users of materials and products, beyond the end user/consumer (who are themselves multiple). This broadening of the scope of materials design research to that of multiple environments of the designer has implications of its own, particularly so when considered in terms of the deeply embedded cultural categories that coalesce round ideas of nature. So rather than categorising the ways in which materials with different origins affect our relationship to nature, we see a nature-design unity as, using Manzini’s (2016) terms “design culture”. And the history of milk plastics is a good illustration of this, as it suggests that when it comes to materials, there is less contrast between the two terms in “nature-design” than at first appears.

## 3 Material antecedents – milk, bacteria, mould

Tracking a material to its origin to identify its real character is a method that Seetal Solanki proposes on her online platform “ma-tt-er”. Clearly such an enquiry resonates with current interest into where things come from, a reflection of our awareness that origins matter because of their social and ecological effects. And of course, it reflects our sociological interest as the authors of this article, in how things come to be and how they circulate through multiple contexts, within Manzini’s “design culture”.

The story of Casein plastics – from surplus liquid to useful material to anachronism – mirrors the trajectory of plastics from trash (side-effect of petroleum distillation), to product, to trash. In it we can see its values for the communities involved with it and the values and qualities of different materialisations of milk and plastics. Closely connected to the life and livelihood of many humans and animals, milk is sometimes, palpably sour and smelly, sometimes it is understood as healthy, clean and sanitary, sometimes sustainable, sometimes inferior. A useful way to conceptualise these dynamic and multiple meanings is offered by Callon, Méadel, and Rabeharisoa (2002) who propose that goods are differently “qualified” in and through different actors with which they interact. Hence, to understand materials, we must look at them in their multiple environments and meanings. Consequently, in this story we will track how relations unfold around the various actors relevant to milk and plastics and attempt to conceptualise the resultant matter among changing conceptions of milk, bodily fluids, mould, bacteria, hygiene, daily life, nature, and sustainability – portraying a wide array of materialities and relationships.

Among these categories, are both positive and negative themes – they are a contradictory mix. A material made from milk (or mould) may be considered authentic, and therefore valuable, but also *dirty* – it is the origin of pathogens. The discovery of the relationship between bacteria and disease in the nineteenth century by Pasteur and others (Worboys 2000), led by the end of that century to a strong association between dust and disease. This “bacteriophobia” is an element in a more complex relationship to nature – a disenchanted one, according to Jens Jørgensen (2015). The properties of plastics have been figured as an antidote to this modern, antipathy for the dirtiness of nature – their seamless surfaces valued for this reason (Forty 1986). Plastics emerged as part of a material culture that was increasingly aware of the risk to health of pathogens carried in dust, and they allowed a “clean” modern style. And they were actually clean because they could be cleaned, disinfected. The twentieth century synthetic plastics gave us hope of control because of their sheer ‘wipe-clean’

surfaces. In their war-time book on plastics Yarsley and Couzens' image of the life of 'plastic man' emphasised that plastic goods have "no crevices to harbour dirt or germs" (1941), nowhere to harbour unruly nature. In the modern world nature can be controlled, but also is always beyond human control, bacteria are both homely, they are in us and of us, and they are frightening, they are against us.

Before thinking more specifically these 'biotic' materials, new and old, unformed and vilified, it is useful to track their origins in milk, and their antecedents, which we find in glue and varnish. Milk was known as a source of sticky stuff when Cennino Cennini wrote these instructions for making glue out of cheese:

> *There is a glue used by workers in wood; this is made of cheese. After putting it to soak in water, work it over with a little quicklime, using a little board with both hands. Put it between the boards; it joins them and fastens them together well.' (Cennini, 1954 (ca1400): 68)*

In a long arc of time, the novel approaches to producing materials using the action of fungi and other organisms in the 21st Century can be connected to this glue made from mouldy milk, though the industrial process that developed in the late nineteenth century sought to 'de-nature' the material – to use the chemical constituents of milk rather than its propensity to grow mould. It was the casein protein in the milk that formed Cennini's glue, though processed by mould rather than by chemists. By the end of the nineteenth century chemists had analysed the properties of the casein molecule to produce a useable plastic material, perfected from 1897 when two Germans, Spitteler and Krische made a durable and waterproof material by treating casein with formaldehyde. The material was patented in 1899 as Galalith – literally translated from Greek and Latin as "milk stone" (Plastiquarian, n.d.).

## 4 Progressive modern plastics

The plastics industry was sufficiently well established by 1929 to support a trade paper, *British Plastics and Moulded Products Trader.* Its first volume included articles about casein plastics in each issue that cover potential applications for the materials and technical issues, and they outline the origin of the materials. These suggest its characterisation had a complex relationship between ideas of "nature" and "modernity", based on the clues in these articles to the names the material was being given.

A search has revealed around 100 casein-derived plastics names, of which sixty have a connotation of nature, associating them with stone with the suffix "-lith" (or "-lit", "-lite", "-it"), as in Galalith. Twelve refer directly to casein's origin in milk, using the prefix "lac-" or "cas". Ten use the suffix "-oid". "-oid" literally indicates likeness – from the Greek *oiedēs* meaning "likeness" or "form of", which itself derives from *eidos*, meaning *form* (Collins, n.d). Several of the names for casein plastics use the "-oid" suffix as in Cassoid or Lactoloid, implying the plastic is *like* milk, which it is not, really, being a material not a foodstuff.

The suffix "-oid" brought a progressive connotation to casein plastic, by connecting it to what was by the early 20th Century a successful new material, Celluloid, already common as a replacement for items such as starched collars and tortoiseshell brush and mirror backs by the late nineteenth century (Friedel, 1983: 119). The rhetoric of the Italian Futurists used this overtly progressive connotation of new materials. Emily Braun (1995) arguing for the influence of the Futurists on the development of Italian fashion, cites the 1920 *Manifesto of Futurist Women's Fashion*. Here, with an echo of the rhetoric surrounding contemporary "growing design", its author "Volt" (Vincenzo Fani) encourages fashion designers to "fling open the doors of the fashion ateliers to paper, cardboard, glass, tinfoil, aluminium, ceramic, rubber, fish skin, burlap, oakum, hemp, gas, growing plants and living animals".

It is only a small step from these provocative quasi-materials to fashion made of milk, and it was a step that Mussolini's government took, by supporting the development of Lanital, a casein based wool substitute. Lanital was developed in the face of trade sanctions after Mussolini's invasion of Ethiopia in 1935, and used for service uniforms. It had some of the properties of wool, as well as one extra, and unpopular, one. It smelt like sour milk when it got wet. This smell, part of the material's "lively materiality" (Bennett, 2010) inadvertently connected casein to its natural origin – an aromatic and slightly unpleasant connection that perhaps contradicted the futuristic connotation that Marinetti and Mussolini would have preferred. Just as milk resisted categorisation, or quickly got sour or crème-like in the chemistry laboratory as Orland tells (2009), the milky origin of Lanital – its "soul" – exerted itself in its associations and valuation.

Despite this unwelcome return of the material's repressed nature, some contemporary accounts emphasised casein's natural origins, in terms of both its source, with its connotations of a natural lifestyle, and its production, which required traditional crafts methods. A 1929 article in *British Plastics* described the British Erinoid company, emphasizing the rural beauty of the factory's location in an old converted woollen mill. Erinoid was set up in 1914, in Stroud, Gloucestershire to make "Erinoid", a casein plastic. This was timely as the outbreak of war cut off supplies of Galalith to the UK – by then essential for making the buttons for service uniforms. The article describes a semi-mechanised process with significant craft elements that included the hand-work that was necessary to compensate for the irregularities of the product. The surface of the material was initially rough and had to be polished. Rods came out at different diameters. Sheets were buckled after the "seasoning" in formaldehyde that was needed to turn a hard, brittle material into a tough and usable one.

The first attempts to make a casein plastic, 'Syrolit', at Stroud were in 1909, and several papers at the time referred to "the making of buttons from milk" (Hull Daily Mail, 6th April 1909). The *British Plastics* article calls Erinoid a 'progressive' company, however, the company itself promoted its material in *British Plastics* as 'artificial horn' – a backward looking association that aligned with the by then firmly embedded characterisation of plastics as substitute materials. The imitative use of celluloid and its consequent characterisation as a cheap, low quality substitute – ersatz – which promoted social dissembling, reached a point by the nineteen sixties where the word 'plastic' could be applied to any thing, or person not considered to be genuine. (Meikle 1995: 290). The outline of casein's development in *British Plastics* from 1930 used similar terms, noting that Krische and Spitteler patented it as 'Plastic Compositions: ivory artificial, horn artificial, amber artificial, wood treating'. However, it ends by associating the material with innovation: 'The future holds great promise for this comparatively new product. Its beauty and charm as a decorative material have not yet been full appreciated by the public' (Dodd 1930: 478).

The way this narrative emphasises both Erinoid's modernity, and its sylvan origin, indicates that there is no necessary connection between a natural source and what is taken to be authentic and innately valuable, in fact if the reporting on Erinoid had been for a general rather than a trade readership, its association with the countryside might be taken as evidence of a desire to counter the association with fakery that plastic had already accrued by the 1930s.

## 5 Plastics and nature, new and old

So we have materials from natural sources, past and present, industrial and pre-industrial. Casein simply comes from milk – cows produce the protein that is then chemically manipulated into the plastic. In contrast contemporary developments promise biotic materials that generate artefacts by "growing design". This is not simply using nature as a source of material that is then manipulated, they come about from letting nature 'do its own thing' in a more or less managed way, preserving some of the **autonomy** of the organisms that are directly producing the material. Carole Collet (2013) describes an approach to new materials, among other four categories, a fifth category that relies on "**hacking"** nature's components, not to use the bits as components of polymers like with

casein, or cellulose, but to re-program organisms in a way that preserves their autonomy, but has them "do a different thing". In a way this "hacking" is not essentially new in the context of human modifications to the environment. In relation to materials, heating up horn and bending it into desired shapes can also be regarded as hacking, in that it changes the material to conform to a human intention.

*Nature* is clearly the significant cultural category in the characterization of these new materials. Nature is implied by casein's milky source and by the more autonomous biotic examples. In one a 'natural' material – cows milk – is clearly a resource, perhaps therefore having some characteristics in common with material we find in the ground, or growing on it. In the other we are perhaps harnessing the power of nature to create material, instead of finding materials in the stuff nature provides.

However, to understand how these materials come to be, the task is not so much to categorise our relationship to nature, or nature's relationship to new materials, but rather to look at the "nature" of this relationship, by taking up the challenge to think all materials as active agents. For when we act on materials they act on us, when nature changes materials, materials change nature as well. Bensaude Vincent and Newman (2007:1), give the examples of "a glowing jellyfish injected with a phosphoric material, or a genetically modified corn" and argue that these are still natural beings, yet our categorisations related to nature has changed and so has the materials. And their existence puts into question what can be termed natural and what cannot. We need to think about what we mean by nature in each case, but this is not simple because of the tangled circulation of ideas that coalesce round this 'most complex' concept (Williams 1976). However, it is clearly this concept that that gives both synthetic and biotic materials their *meanings* (McCracken 1986).

Raymond Williams outlines three senses of "nature": first, nature as something's essential quality, as in "my true nature"; second, as the "inherent force that directs either the world or human beings, or both"; third as the material world itself, either containing or not containing humans. He notes that the root of the word is in the Latin "nasci", to be born – from which we get the sense of nature as origin, the place things come from, and the words native, nation, innate etc.

This last sense links both casein plastics and contemporary 'growing design' to nature by simply indicating that they *have* an origin, with the gloss that both are 'biotic'; they have animal/vegetable rather than mineral origins. However, while the fact that they are not from fossil sources associates them with the **autonomy** of animals and plants that live and reproduce, this fact alone says little about what the materials are taken to be – their qualities – or the implications of that natural origin for our valuation of them.

Williams' third sense of "nature" may help with this, acknowledging that humans sometimes include themselves in the category 'nature', and sometimes not, and it may be easier to do this in relation to the 'nature' of materials that originate in the farmyard, or the greenhouse, than for materials from the laboratory and the refinery. We can perhaps imagine living in a farmyard or greenhouse, but not in a refinery and so it may be easier to identify with 'biotic' materials – they seem *more* natural and therefore more human. This connection, with a common-sense idea of nature as that which is not human but is "humane", might assuage concerns about their novelty, their strangeness. We may more easily find Ingold's "correspondance" in such materials.

Recent work in STS stimulated by concerns about the permanence of the twentieth century synthetic materials and their appearance 'out of place' (Douglas 1966) in the oceans offers us another way to think about these paradoxical relationships between materials and nature. In a recent ethnography of Pacific oceanographers who quantify the plastic in the ocean Kim De Wolff (2017) sailed with Algalita Marine Research and Education, founded by Charles Moore, who named the Pacific 'garbage patch'. This work is about the effect of 'old-new' materials – the ubiquitous synthetics of the twentieth century, which in the early twenty first century seem poisonous, too permanent and too costly to an abstract sense of 'nature' in Williams' second sense.

Williams points out that ideas about nature are always ideological. The idea of nature: "played critical roles in arguments about, first, an obsolete or corrupt society, needing redemption and renewal, and, second, an 'artificial' or 'mechanical' society, which learning from Nature must cure." He equates these two positions with Romantic and Enlightenment thought, noting the role of "newly scientific generalisation: 'Nature teaches . . .' 'Nature shows us that . . .'" emphasising that what was shown or taught could range "from inherent and inevitable bitter competition to inherent mutuality or co-operation." (1976: 223-4)

So there is a political dimension to this discussion, given the current variety in political engagement with the consequences of human actions for environmental sustainability. 'Biotic' materials are informed by the subtle and complex insights into the nature/ culture relationship that derive from STS, which should re-calibrate our ideas about that relationship. In the process of doing the science of oceanography, studying the interface between plastic and non-plastic – "live" – matter in the ocean it is impossible to properly distinguish the two, practically, when categorising the matter under the microscope, and in terms of ethical decisions about what to do about some of the plastic artefacts that float about supporting colonies of marine life. Kim De Wolff describes the impossibility of distinguishing "plastic" from "real" in the samples that the Algalita crew collect – if bits of jellyfish have plastic particles inside them are they "real" (natural) or not?

## 6 Conclusion

DeWolff's work in the "plastisphere" – the indeterminate zone round plastics in the ocean that is not clearly either nature or culture, suggests an indeterminate, troubled relationship to nature that plays out in her suggestion that "plastics are named as potential species" because of our entanglement with them, past and future (2017: 5). In these terms, it is not clear how to assess contemporary design interventions into the world of new materials. They might be proposed as a solution to a problem – that's how designers often think – the problem being one of too persistent materials that disturb our relationship with nature. But framing the problem that way preserves the nature/culture split that STS suggests is not tenable, or useful, any longer. They are perhaps not a solution then, and the "bio-design fiction" examples certainly are not, since they exist only in the imagination. Taken as a whole, this design work has an attractive coating of concern for human-nature relationships, appealing to Williams' second sense of a nature that includes humans and generating materials that are to some extent autonomous, part of a 'natural rhythm' that can die as well as live. However, this palliative "autonomy" may mask the strong sense of a categorical human-nature split – a nature that does not contain humans, but over which humans have dominion that is evident in the "augmented biology" dimension of new materials work. Here, as Camere and Karana (2017) suggest, nature is hacked through digital fabrication, with "nature" carrying the sense of "not containing humans", a material world that is available to us to manipulate through bio-hacking. So these materials seem to reproduce the equivocal and entangled relationship between humans and nature, rather than being a solution to any problem (as yet to be defined precisely). As such, rather than a solution, this entanglement might point to a pattern, in which nature and culture feed back into each other, as the new unit of analysis, through which new materialities are enacted with the co-working, or as Ingold (2017) puts is with the "co-respondance" of material and social "knots."

However, they are a novelty, and in their relationship to our continuing adaptation to material purposes of the substances people find in the world they are clearly in the same tradition as the work that produced casein plastics. There are some symmetries between the two. The milky smell from Lanital betrayed its biological origin and another *British Plastics* article observed that casein in preparation is an excellent medium in which to grow microorganisms, which connects it both to Cennini's cheese-based adhesive and to new materials made from fungi (Poultney, 1929: 28). There was a trajectory from stuff to decay because the waste from casein plastics couldn't be recycled in the manufacture of new material, making 'artificial manure' was the only productive solution ("Technician", 1930). Casein went from material to muck. Material produced from fungus goes from

muck to material (then to muck). The new biotic materials add to this passive decay an element of autonomy, and for this reason, they could perhaps be characterised as a new class of materials, the "autonomoids".

However, these principles apply to any material, in that every material has its own incipient physical tendencies, enacted in their various contexts. Their qualities occur 'naturally', i.e. spontaneously, in different ways whether they have been put there by chemistry or chance. As such, materials in design cannot be seen as categorisations of nature, or simple manipulations of nature; materials change nature and nature changes them. As humans' relations to nature's use and value changes, so do our relationships to materiality. Casting materials into the world as autonomoids troubles our categorisations of humans' relationship to nature, and rejects placing ourselves against nature in the sense of manipulating or disturbing it. Nature as a human concept evolves with our materiality, however it also has its active liveness. From this point of view, designers cannot 'hack' nature or materials. They can work with them, and cannot force them to come up with desired outcomes or interactions. Designers perhaps will do best if they get to know their autonomoid colleagues, and work with their tendencies and put their creativity into work in thinking about their possible enactments, which might be material as well as social.

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